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CONTROL METHOD OF MAGNETRON INVERTER POWER SOURCE
[MAGUNETORON YOO INBAATA DENGEN SEIGYO HOOHOO]

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Specfication

1. Name of the Invention

Control Method of Magnetron Inverter Power Source

2. Claims

(1) A control method of a magnetron inverter power source, being characterized in that a magnetron inverter power source for driving a magnetron at a high frequency voltage obtained by an inverter is equipped with a means for detecting an input of a commercial frequency voltage of said inverter, a means for establishing a standard to arbitrarily set a high frequency output of said magnetron, a means for comparing and calculating an output of said detecting means and an output of said reference establishing means, a frequency conversion means for varying a switching frequency of said inverter according to an output of said comparison computation means, a means for suppressing a voltage current surge caused by a transient phenomenon generated when said inverter and said magnetron start to operate, and a means for driving a power switching element of said inverter wherein it operates at a highest switching frequency for a given time when said inverter starts to operate, and then operates at a switching frequency equivalent to a high frequency in low power for a given time, and thereafter operates

at a switching frequency equivalent to a set high frequency output.

(2) The control method of a magnetron inverter power source, being characterized in that a magnetron inverter power source for driving a magnetron at a high frequency voltage obtained by an inverter is equipped with a means for detecting an input of a commercial frequency current of said inverter, a means for establishing a standard to arbitrarily set a high frequency output of said magnetron, a means for comparing and calculating an output of said detecting means and an output of said reference establishing means, a frequency conversion means for varying a switching frequency of said inverter according to an output of said comparison computation means, a means for suppressing a voltage current surge caused by a transient phenomenon generated when said inverter and said magnetron start to operate, and a means for driving a power switching element of said inverter wherein it operates at a switching frequency equivalent to a high frequency in low power for a given time when said inverter starts to operate, and thereafter operates at a switching frequency equivalent to a set high frequency output.

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(3) The control method of a magnetron inverter power source, being characterized in that a magnetron inverter power source for driving a magnetron at a high frequency voltage obtained by

an inverter is equipped with a means for detecting an input of a commercial frequency current of said inverter, a means for establishing a standard to arbitrarily set a high frequency output of said magnetron, a means for comparing and calculating an output of said detecting means and an output of said reference establishing means, a frequency conversion means for varying a switching frequency of said inverter according to an output of said comparison computation means, a means for suppressing a voltage current surge caused by a transient phenomenon generated when said inverter and said magnetron start to operate, and a means for driving a power switching element of said inverter wherein it starts at a highest switching frequency when said inverter starts to operate, and gradually drops at a switching frequency equivalent to a set high frequency output for a given time.

3 . Detailed Description of the Invention

Field of Industrial Application

This invention relates to a control method of a magnetron inverter power source.

Prior Art

Conventionally, according to a magnetron power source to drive a magnetron at a high voltage obtained by pressurizing a commercial frequency voltage by a high pressure transformer and

further by a voltage double rectifier circuit consisting of a high pressure capacitor and a high pressure diode, it is possible to make a high pressure capacitor variable with a high frequency output obtained by the magnetron or by duty controlling a voltage to apply to a high pressure transformer.

However, in order to obtain a plurality of types of high frequency outputs by making the high pressure capacitor variable, it is necessary to utilize a high pressure capacitor having a capacity according to each high frequency output, which results in a cost increase and requires more space. Since according to the duty control method for applying a voltage to the high pressure transformer, a high frequency output is obtained as an average value by varying a time interval of a full-power oscillation and a suspension of an oscillation, and an oscillation and a suspension of the magnetron are repeated, thereby affecting the life of the magnetron adversely.

According to both of the said methods, it was impossible to continuously vary the high frequency output.

Furthermore, since the high pressure transformer was utilized at a commercial frequency, the shape and the weight thereof were large, thus blocking miniaturization and weight reduction of the magnetron power source.

In recent years, due to the miniaturization and the weight reduction of electronic devices, the power sources have changed

to switch-type sources, and the magnetron power source has also changed to a switch-type source, that is to say, it has been inverted, wherein it is possible to realize the miniaturization and weight reduction. One example of a basic circuit of a magnetron inverter power source will be described according to Fig 1.

Primary winding wire 5p of insulation transformer 5 consisting of primary, secondary, tertiary winding wires is connected to resonance capacitor 4 in parallel, said primary winding wire 5p is connected to power switching element 6 in series, said power switching element 6 is connected to fly wheel diode 7 in parallel, a pulsating output in which commercial power source 1 is rectified and smoothened by rectification bridge 2 and smoothing capacitor 3 is added at the both ends of the circuit, wherein said primary winding wire 5p is connected to power switching element 6 in series, thereby constituting the primary circuit; secondary winding wire 5s is connected to magnetron 8 in parallel, thereby constituting the secondary circuit; and tertiary winding wire 6t is connected to the heater of said magnetron 8 in parallel, thereby constituting the tertiary circuit; thus said primary, secondary, tertiary circuit comprising the circuit.

The operational principle of this inverter will be described according to Fig 2. When a forward direction voltage

is applied between the base and the emitter of power switching element 6, power switching element 6 becomes energized, voltage E is applied to primary winding wire 5p of insulation transformer 5 by smoothing capacitor 3 in which energy is stored by direct current power source E such that current I_{N1} flows in the direction as illustrated, thereby storing the energy in primary winding wire 5p. Next, when a backward direction voltage is applied between the base and the emitter of power switching element 6, power switching element 6 becomes disconnected, and by the energy stored in said primary winding wire 5p, the inductance portion of primary winding wire 5p and resonance capacitor 4 resonate in parallel, thereby generating a high resonance voltage $-V_{N1}$ (opposite direction to the one in the drawing) at the both ends of primary winding wire 5p. The

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resonance voltage is further pressurized by secondary winding wire 5s so as to be supplied between the anode and the cathode of magnetron 8. The polarity of said primary winding wire 5p and secondary winding wire 5s is homopolarity as illustrated in the drawing, and they are connected when magnetron 8 oscillates when power switching element 6 is disconnected. The polarity of tertiary winding wire 5t to be connected with the heater of magnetron 8 has no relevance, and it must have a coil turn to depressurize V_{N1}.

Herein, if the inductance of said primary winding wire 5p is L, and the conduction time of power switching element 6 is t_{ON}, current I_{N1} is $E/L \cdot t_{ON}$, the energy to be stored in primary winding wire 5p becomes $1/2\ LI_{N1}^2$, wherein a change in t_{ON} changes I_{N1}, thereby changing the energy stored in primary winding wire 5p, and changing the energy stored in magnetron 8. This means that if the disconnection time of power switching element 6 is t_{OFF}, switching frequency f is $1/(t_{OFF} + t_{OFF})$, and hence making t_{OFF} constant while changing t_{ON} is equivalent to changing f. As illustrated in Fig 3, since there are linear relations between switching frequency f and the high frequency output of magnetron 8, between the switching frequency and the input of the commercial frequency current, and between the commercial frequency current and the high frequency output respectively, it is possible to continuously vary the high frequency output by detecting the input of the commercial frequency current so as to change the switching frequency f. This control algorithm can be also applied to said secondary circuit consisting of a voltage double rectifier circuit or a rectifier smoothing circuit and to the tertiary circuit consisting of a rectifier smoothing circuit.

Problem to Be Solved by the Invention

When the inverter starts to operate, a surge current flows into power switching element 6 for about several cycles due to the transient phenomenon. Furthermore, because the power is

supplied to the heater through tertiary winding wire 5t of insulation transformer 5, only after the inverter starts to operate, the heater is heated, hence it takes some time before the heater is warm enough such that the emission amount reaches a level required for magnetron 8 to oscillate, wherein the peak of corrector current I_C and the voltage of secondary winding wire 5s flowing into power switching element 6 for about several cycles due to the transient phenomenon when magnetron 8 starts oscillation becomes about 1.5 to twice as many as those under the normal operation. Therefore, there was a problem if it was started at a low switching frequency so as to obtain a large high frequency output, power switching element 6 was destroyed due to excessively large flow of corrector current I_C.

Means for Solving the Problem

In order to solve the above problem, according to the control method of a magnetron inverter power source of this invention, a magnetron inverter power source for driving a magnetron at a high frequency voltage obtained by an inverter is equipped with; means for detecting an input of a commercial frequency voltage of said inverter, means for establishing a standard to arbitrarily set a high frequency output of said magnetron, means for comparing and calculating an output of said detecting means and an output of said reference establishing means, frequency conversion means for varying a switching

frequency of said inverter according to an output of said comparison computation means, means for suppressing a voltage current surge caused by a transient phenomenon generated when said inverter and said magnetron start to operate, and means for driving a power switching element of said inverter; wherein it operates at a highest switching frequency for a given time when said inverter starts to operate, and then operates at a switching frequency equivalent to a high frequency in low power for a given time, and thereafter operates at a switching frequency equivalent to a set high frequency output.

That is to say, it is realized by the constitution as illustrated in Fig 1. As illustrated in Fig 1, it comprises detection circuit 10a in which an input of a commercial frequency current is detected by a current transformer, rectified, and smoothened so as to be converted into a voltage; reference circuit 10b for establishing a reference voltage; comparison computation circuit 10c for comparing the output voltage of said detection circuit 10a and the output voltage of reference circuit 10b so as to compute a result thereof; frequency conversion circuit 10d for converting the output voltage of said comparison computation circuit 10c into a high frequency pulse; drive circuit 10f for driving power switching element 6 with a high frequency output pulse of said frequency conversion circuit 10d; and soft start circuit 10e for driving

at a highest frequency for several milliseconds when said drive circuit 10f starts, and then switching to a frequency equivalent to a high frequency output in low power for several seconds, and thereafter transferring to a frequency equivalent to a given high frequency output.

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Operation

According to the above constitution, the higher the frequency of the high frequency pulse to drive power switching element 6 is, the smaller the peak of corrector current I_C is, hence, it is possible to suppress the surge current for several cycles flowing in power switching element 6 caused by a transient phenomenon produced when the inverter starts, that is to say, when drive circuit 10f starts, by operating it at a highest frequency for several milliseconds. Thereafter, while it is driven for several seconds at a frequency equivalent to the high frequency output in low power (about 200 W), the heater of the magnetron is sufficiently heated, thereby the magnetron starts oscillating in low power. At this time, the peak of corrector current I_C is higher than normal for several cycles due to the transient phenomenon when the magnetron 8 starts to oscillating, however, the high frequency suppresses the peak of corrector current I_C, hence it does not destroy power switching

element 6. Thereafter, it shifts to a frequency equivalent to given power so as to continue normal oscillation.

Either according to the method wherein soft start circuit 10e operates at the switching frequency equivalent to the high frequency output in low power (about 200 W) for several seconds when said drive circuit 10f starts and then operates at the switching frequency equivalent to the given high frequency output, or according to the method wherein it starts at the highest switching frequency and then gradually drops to the switching frequency equivalent to the given high frequency output for several seconds, as described above, it suppresses the peak of the surge due to the transient phenomenon.

Embodiments

A specific embodiment to realize this invention will be described below.

In Fig 4a, it comprises detection circuit 10a in which an input of a commercial frequency current is detected by a current transformer, rectified, and smoothened so as to be converted into a direct current voltage; reference circuit 10b for producing a voltage to set an arbitrary high frequency output of the magnetron as a reference; comparison computation circuit 10c for comparing the output voltage of said detection circuit 10a and the output voltage of reference circuit 10b so as to compute a result thereof; frequency conversion circuit 10d for

converting the output voltage of said comparison computation circuit 10c into a high frequency pulse; drive circuit 10f for driving a power switching element with a high frequency output pulse of said frequency conversion circuit 10d; soft start circuit 10e for driving at a highest frequency for several milliseconds when said drive circuit 10f starts, and then switching to a frequency equivalent to a high frequency output in low power for several seconds, and thereafter transferring to a frequency equivalent to a given high frequency output.

The operation of comparison computation circuit 10c of this control circuit will be described.

First, the output voltage of said detection circuit 10a is compared to the output voltage of reference circuit 10b with comparator 1; when the output voltage of detection circuit 10a is lower than the output voltage of reference circuit 10b, the output of comparator 1 swings to a positive maximum value; when the voltage thereof is inverted and amplified by operational amplifier 2, it drops below 1/2; the difference between the output voltage of reference circuit 10b and the output voltage of said operational amplifier 2 is obtained by operational amplifier 3; when it is further inverted and amplified by operational amplifier 4, it drops below 1/2; furthermore, the difference between the reference voltage decided by operational amplifier 5 at VR and the output voltage of said operational

amplifier 4 is obtained so as to transmit it to frequency conversion circuit 10d.

If the voltage at this time is V_1 and the output voltage of detection circuit 10a is higher than the output voltage of reference circuit 10b, the output of comparator 1 swings to a negative maximum value. Hereafter, if computations are executed similarly to the above, the output voltage of operational amplifier 5 becomes V_2 and $V_1 < V_2$.

The relationship between the input voltage of said frequency conversion circuit 10d and the frequency of the high frequency output pulse is as illustrated in Fig 5, and when the output of the detection circuit 10a is lower than the output voltage of reference circuit 10b to set a high frequency output of the magnetron, drive circuit 10f operates at low frequency f_1 so as to increase the input of the commercial frequency current, and when the output voltage of detection circuit 10a is higher than the output voltage of reference circuit 10b, it operates at high frequency f_2 so as to suppress the input of the commercial frequency current, thereby keeping the high frequency output constant.

That is to say, if the high frequency output at low frequency f_1 is W_1 and the high frequency output at a high frequency is W_2, $W_1 - W_2$ is ΔW, it is controlled in a range of

plus minus $\Delta W/2$ around the set high frequency output, thereby obtaining the set high frequency output as an average value. Fig 4b illustrates only the comparison computation circuit as other control method. Compared to the above method allows a range of control, according to this method, the difference between the input of the commercial frequency current and the set reference value is computed so as to make it zero such that the frequency in which the difference reaches zero becomes equivalent to the set high frequency.

In soft start circuit 10e, when start switch SW is closed, voltage A is applied to the input of frequency conversion circuit 10d for several milliseconds, and thereafter voltage B is added for several seconds, wherein the output voltage of comparison computation circuit 10c is applied. Therefore, it is possible to suppress the surge current for about several cycles flowing in power switching element 6 caused by a transient phenomenon produced when the inverter starts, that is to say, when drive circuit 10f starts, by operating it at a highest frequency (the frequency decided by voltage A) for several milliseconds, wherein the heater of the magnetron is sufficiently heated while it is driven at a frequency (the frequency decided by voltage B) equivalent to the high frequency output in low power (about 200 W) for several seconds, thereby

the magnetron starts oscillating in low power. At this time, the peak of corrector current I_C is higher than normal for about several cycles due to the transient phenomenon when the magnetron starts oscillation, however, the high frequency suppresses the peak of corrector current I_C, hence it does not destroy power switching element 6. Thereafter, it shifts to the frequency equivalent to the given power (the frequency decided by an output voltage of comparison computation circuit 10c) so as to continue the normal oscillation.

Other soft start methods are illustrated in Fig 4c and Fig 4d illustrating only the soft start circuit, wherein similarly to the soft start method described above, the peak of the surge due to the transient phenomenon at the start time is suppressed. Fig 4c illustrates the soft start circuit according to a method in which it operates at a switching frequency equivalent to a high frequency output in low power for several seconds when drive circuit 10f starts, and then operates at a switching frequency equivalent to a given high frequency output; Fig 4d illustrates the soft start circuit according to a method in which it starts at a highest switching frequency and then gradually drops to a switching frequency equivalent to a given high frequency output for several seconds.

This control circuit method produces the following effects:

(1) Since it is possible to suppress the current surge due to the transient phenomenon when the inverter starts and the current surge (1.5 to twice as many as those under the normal operation) due to the transient phenomenon when the magnetron starts oscillation, it is not necessary to select the current rating of the power switching element more than necessary, thereby realizing the cost-cutting.

(2) Since it is a feedback control method for detecting an input of a commercial frequency current, compared to the current detection method for the high pressure circuit of the high pressure transformer secondary side, it makes the insulation easier and the cost less expensive.

(3) Since the current surge due to the transient phenomenon is suppressed when the inverter and the magnetron start to operate, it is possible to suppress the voltage peak generated in the secondary winding wire of the high pressure transformer, thereby making the insulation of the transformer easier and realizing the cost-cutting.

Effect of the Invention

This invention produces the following effects:

① It is possible to arbitrarily set a high frequency output of the magnetron by the volume setting of the reference circuit, and furthermore to obtain the high frequency output continuously and variably.

② If the high frequency pulse is applied to the base and the emitter of the switching element continuously, the duty control similar to the conventionally practiced is realized, wherein combined with the continuous control, a variety of high frequency output are available.

③ Since it starts with a high frequency, it is possible to suppress the peak of corrector current I_C due to the transient phenomenon when the drive circuit starts, and then it operate at the frequency equivalent to the high frequency output in low power (about 200 W), the heater of the magnetron is sufficiently heated; and since it is possible to suppress the corrector current due to the transient phenomenon when the magnetron starts oscillation, it is not necessary to select the current rating of the power switching element more than necessary, thereby realizing the cost-cutting.

④ Since it is a feedback control method for detecting an input of a commercial frequency current, compared to the current detection method for the high pressure circuit of the high pressure transformer secondary side, it makes the insulation easier and the cost less expensive.

⑤ Since the current surge due to the transient is suppressed phenomenon when the inverter and the magnetron start to operate, it is possible to suppress the voltage

peak generated in the secondary winding wire of the high pressure transformer, thereby

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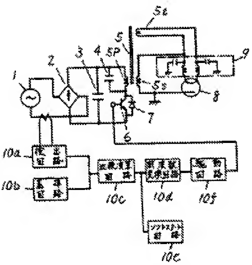
making the insulation of the transformer easier and realizing the cost-cutting effect.

4. Brief Description of the Drawings

Fig 1 is a control circuit diagram of the magnetron inverter power source of one embodiment according to this invention; Fig 2a is a circuit diagram of the major part thereof; Fig 2b is a signal waveform diagram of each part thereof; Fig 3a is a diagram illustrating the relationship between the switching frequency and the high frequency output of the circuit thereof; Fig 3b is a diagram illustrating the relationship between the switching frequency and the input of a commercial frequency current of the circuit thereof; Fig 3c is a diagram illustrating the relationship between the input of a commercial frequency current and the high frequency output of the circuit thereof; Fig 4 is a circuit diagram illustrating the specific embodiment according to this invention; Fig 4b, Fig 4c, Fig 4d are circuit diagrams of the major parts of a specific embodiment according to this invention respectively; Fig 5 is a diagram illustrating the relationship between the input voltage of the frequency conversion circuit and the frequency of the high frequency output pulse.

1: Commercial Power Source; 2: Rectification Bridge; 3: Smoothing Capacitor; 4: Resonance Capacitor; 5: High Pressure Transformer; 5p: Primary Winding Wire; 5s: Secondary Winding Wire; 5t: Tertiary Winding Wire; 6: Power Switching Element; 7: Fly Wheel Diode; 8: Magnetron; 9: High Frequency Filter; 10a: Detection Circuit; 10b: Reference Circuit; 10c: Comparison Computation Circuit; 10d: Frequency Conversion Circuit; 10e: Soft Start Circuit; 10f: Drive Circuit.

[Fig 1]



1: Commercial Power Source

2: Rectification Bridge

3: Smoothing Capacitor

4: Resonance Capacitor

5: High Pressure Transformer

5p: Primary Winding Wire

5s: Secondary Winding Wire

5t: Tertiary Winding Wire

6: Power Switching Element

7: Fly Wheel Diode

8: Magnetron

9: High Frequency Filter

10a: Detection Circuit

10b: Reference Circuit

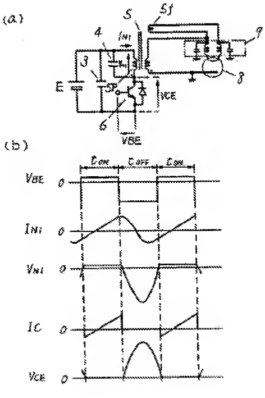
10c: Comparison Computation Circuit

10d: Frequency Conversion Circuit

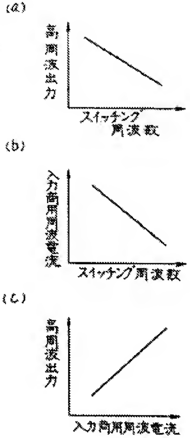
10e: Soft Start Circuit

10f: Drive Circuit

[Fig 2]



[Fig 3]



(a)

[Vertical Axis]: High Frequency Output

[Horizontal Axis]: Switching Frequency

(b)

[Vertical Axis]: Input of a Commercial Frequency Current

[Horizontal Axis]: Switching Frequency

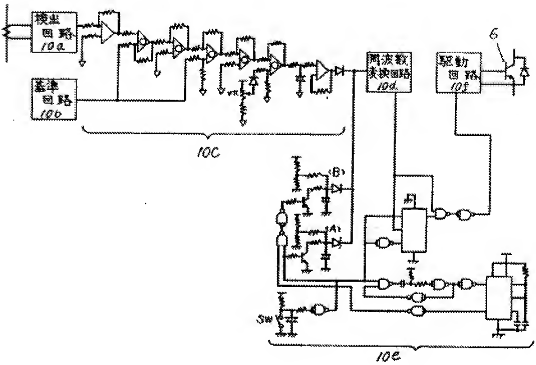
(c)

[Vertical Axis]: High Frequency Output

[Horizontal Axis]: Input of a Commercial Frequency Current

[Fig 4]

(a)



10a: Detection Circuit

10b: Reference Circuit

10d: Frequency Conversion Circuit

10f: Drive Circuit

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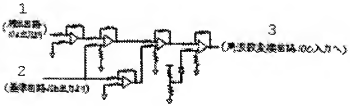
[Fig 4]

(b)

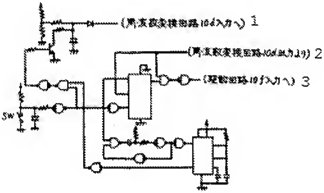


1: (From the output of detection circuit 10a)

2: (From the output of reference circuit 10b)

3: (To the input of frequency conversion circuit 10c)

(c)

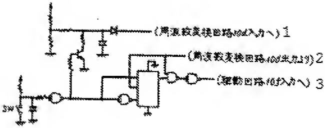


1: (To the input of frequency conversion circuit 10d)

2: (From the output of frequency conversion circuit 10d)

3: (To the input of drive circuit 10f)

(d)

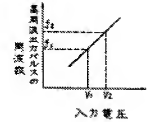


1: (To the input of frequency conversion circuit 10d)

2: (From the output of frequency conversion circuit 10d)

3: (To the input of drive circuit 10f)

[Fig 5]



[Vertical Axis]: Frequency of a High Frequency Output Pulse

[Horizontal Axis]: Input Voltage